LOWER ARKANSAS RIVER BASIN TOTAL MAXIMUM DAILY LOAD

Waterbody/Assessment Unit: Anthony City Lake
Water Quality Impairment: Siltation/Eutrophication

1. INTRODUCATION AND PROBLEM IDENTIFICATION

Subbasin: Chikaskia

Counties: Harper

HUC 8: 11060005

Ecoregion: Central Great Plains, Rolling Plains and Breaks (27b)

Drainage Area: Approximately 21.3 square miles (**Figure 1**)

Conservation Pool: Area = 112 acres (Designed Pool = 155 acres),
Watershed Area: Lake Surface Area = 121:1
Maximum Depth = 3.5 – 4 meters (11.5 – 13.1 ft)
Mean Depth = 1.8 meters (6 ft)
Retention time = 0.23 years (2.8 months).

Designated Uses: Primary Contact Recreation, Expected Aquatic Life Support and Food Procurement Use.

2002, 2004, 303(d) Listing: Table 4 – Water Quality Limited Lakes

Impaired Use: Expected Aquatic Life Support

Water Quality Standard: Suspended solids - Narrative: Suspended solids added to surface waters by artificial sources shall not interfere with the behavior, reproduction, physical habitat or other factor related to the survival and propagation of aquatic or semi-aquatic or terrestrial wildlife (KAR 28-16-28e(c)(2)(D)).

Nutrients – Narratives: The introduction of plant nutrients into streams, lakes or wetland from artificial sources shall be controlled to prevent the accelerated succession or replacement of aquatic biota or the production of undesirable quantities or kinds of aquatic life (KAR 28-16-28e(c)(2)(A)).

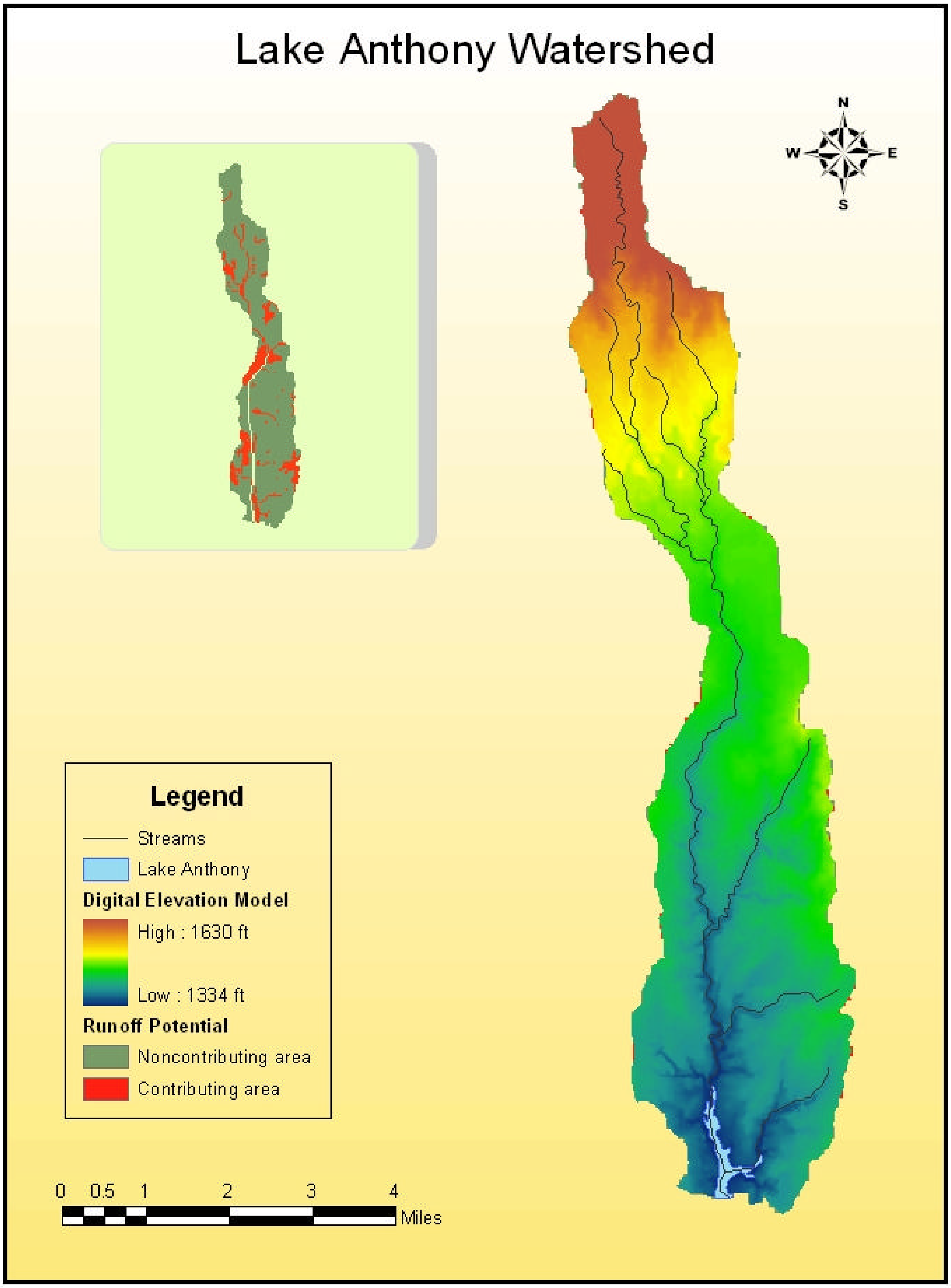

Figure 1. DEM (with runoff potential contributing area) map of Lake Anthony Watershed.

2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Eutrophication: Trophic State Index = 64 (Lower Hypereutrophic), ranging from 44 in 1992 to 76 in 1996.

The Trophic State Index (TSI) is derived from the chlorophyll *a* concentration (Chla). Trophic state assessments of potential algal productivity were made based on Chla, nutrient levels, and values of the Carlson Trophic State Index (TSI). Generally, some degree of eutrophic conditions is seen with Chla over 12 µg/L and hypereutrophy occurs at levels over 30 µg/L. The Carlson TSI derives from the Chla concentrations and scales the trophic state as follows:

1. Oligotrophic TSI < 40
2. Mesotrophic TSI: 40 - 49.99
3. Slightly Eutrophic TSI: 50 - 54.99
4. Fully Eutrophic TSI: 55 - 59.99
5. Very Eutrophic TSI: 60 - 63.99
6. Hypereutrophic TSI: $\geq$ 64

Monitoring Site: Station LM048801 (4-yr rotational monitoring site) in Anthony City Lake.

Period of Record Used: Eight Surveys during 1987 – 2004.

Stream Flow Record: Bluff Creek (Site 07151670, record period from 1968 to 1998) near the City of Anthony, USGS Water Resources Investigation Report 01 – 4142 (Estimated Flow – Duration Curves for Selected Ungaged Sites in Kansas) was used along with Spring Creek duration curve values (USGS, 2004) to estimate flow for Spring Creek above Lake Anthony.

Long-Term Hydrologic Conditions: Spring Creek above Lake Anthony – Median Flow = 1.1 cfs; 10% Exceedance Flow = 6.2 cfs, 90% Exceedance Flow = 0 cfs (**Figure 2**). The estimated mean streamflow was 4.2 cfs. Lake Anthony was built in the 1930's, with a surface area of approximately 112 acres based on a recent KDHE lake inventory data. Estimated lake volume was 657 acre-ft according to a field lake survey conducted by KDHE in 1992 (Carney, 1993). Mean precipitation at Anthony City [National Climatic Data Center (NCDC) – Weather Station ID: Anthony 2W] was 0.85 m (33.5 inches) during the period from 1990 to 2005. The calculated hydraulic residence (retention) time was 2.8 months (0.23/yr).

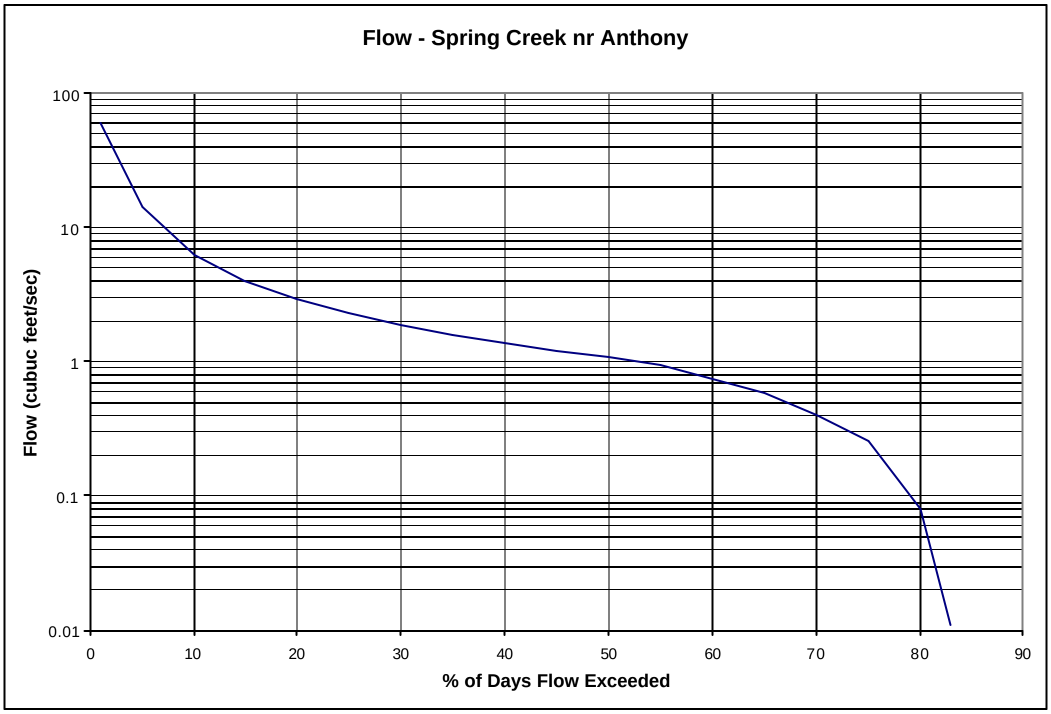

Figure 2. Flow duration at Spring Creek above Lake Anthony.

Current Conditions: Figure 3 and 4 show turbidity and Chla for Station LM048801, respectively. The average Chla (32 µg/L) was above the water quality endpoint for primary contact recreation (12 µg/L). Three sampling events (8/20/1990, 6/17/1996 and 6/28/2004) had Chla over the water quality endpoint for secondary contact recreation (20 µg/L). In general, high Chla appeared when turbidity values were low (< 40 NTU). Turbidity values had a strong negative relationship with Secchi depth readings (**Figure 5**). On average, turbidity and Secchi depth were 92 NTU and 0.16 m during 1997 – 2004, ranging from 28 to 175 NTU and 0.06 to 0.30 m, respectively.

Total phosphorus (TP) concentration averages 274 µg/L and ranges from 220 µg/L in 1987 to 350 µg/L in 1992. Nutrient concentrations of Lake Anthony were compared to other similar lakes in the ecoregion, state and EPA Region VII levels. As indicated in Table 1, Lake Anthony's nutrient values were the highest and over the trophic criteria proposed by the EPA Region VII. An index (Chla/TP) was used to evaluate algal use of phosphorus supply (Carney, 2004). There is a limited response by algae to phosphorus if index are values less than 0.13, suggesting that nitrogen, light or other factors may be more important. If values are greater than 0.4, a strong algal response to changes in phosphorus prevails. The range between 0.13 and 0.4 indicates a moderate response by algal to phosphorus levels. The ratio of total nitrogen (TN) and TP was also used to determine which of these nutrients is most likely limiting plant growth in Kansas aquatic ecosystems (Dzialowski et al., 2005). Generally, lakes that were N limited had water column TN:TP ratios < 8 (mass); lakes that were co-limited by N and P had water column TN:TP ratios between 9 and 21; and lakes that were P limited had water column TN:TP ratios > 29. For Lake Anthony, Chla/TP index values average 0.14 and TN:TP ratios average 6.4, all suggesting that nitrogen and light appear to be the primary limiting factors.

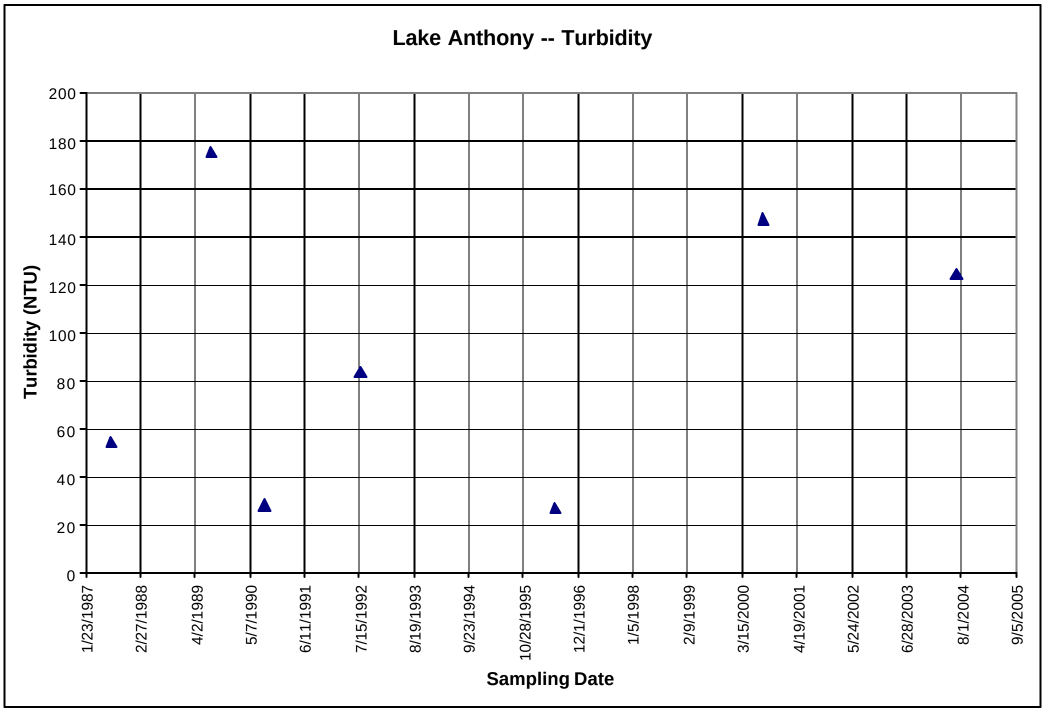

Figure 3. Turbidity concentrations at Site LM048801 during 1987 – 2004.

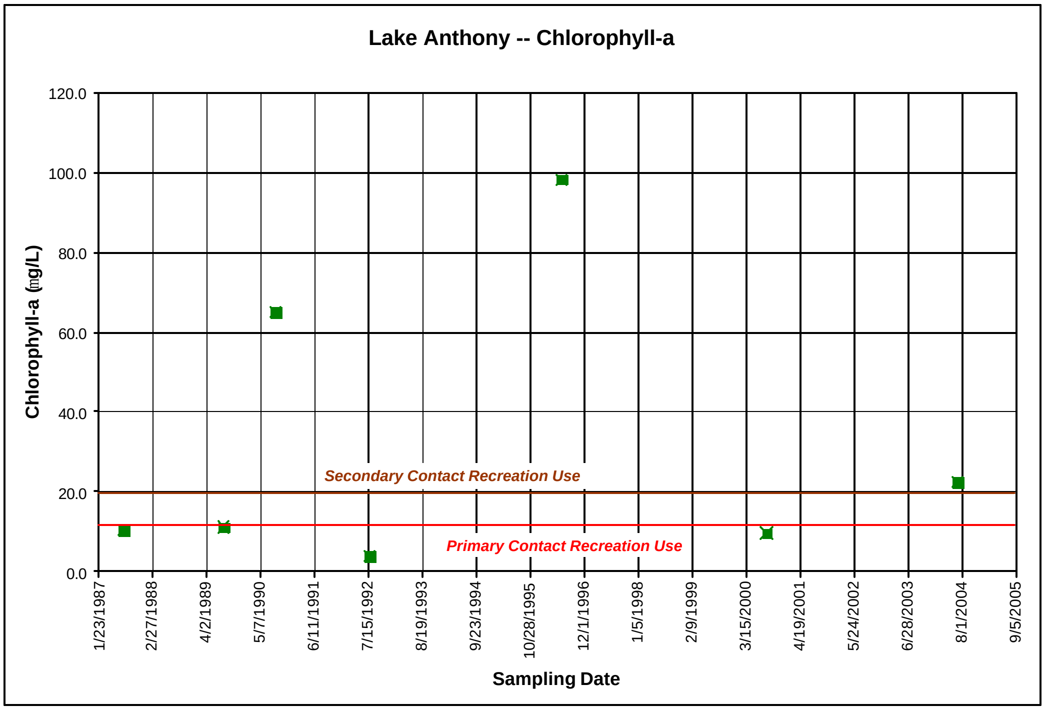

Figure 4. Chlorophyll *a* concentrations at Site LM048801 during 1987 – 2004.

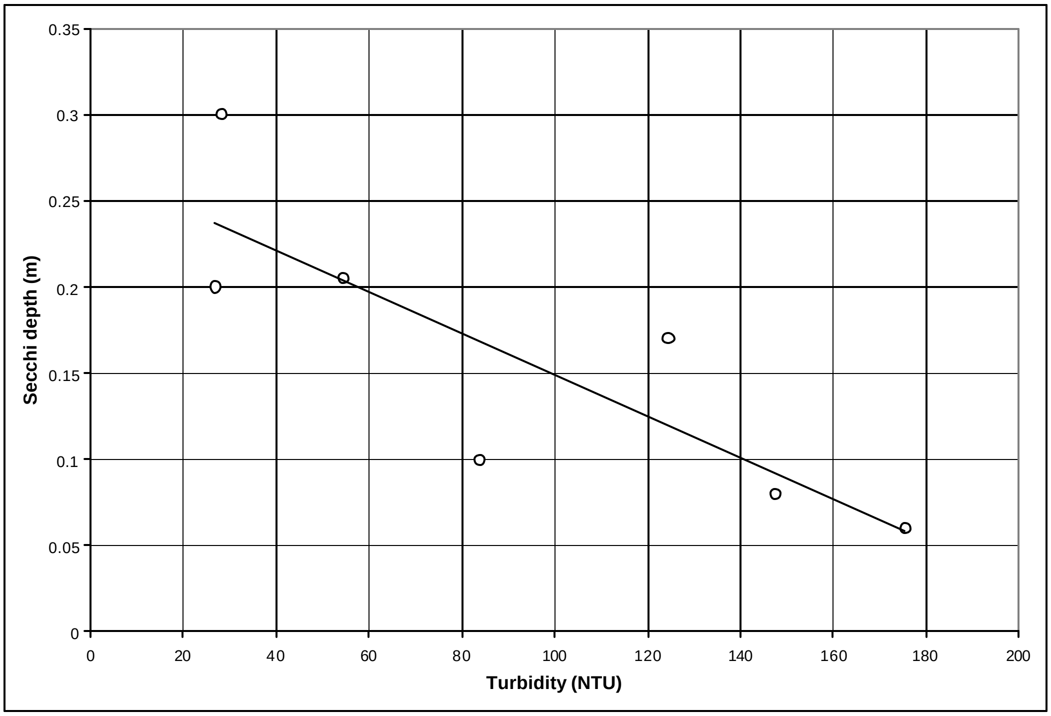

Figure 5. Relationship between turbidity and Secchi depth at Site LM048801.

Table 1. Trophic state of Lake Anthony and its comparisons with other ecoregional, state and regional lakes and reservoirs.

Lake	TN	TP	TN:TP	Chlorophyll *a*	Secchi depth	Non-algal turbidity	Chla/TP
	μg/L	μg/L		μg/L	m	1/m	
Lake Anthony	1,913	274	6.4	32	0.16	8.32	0.14
Central Great Plains[1]	1,258	130	9.0	30	0.64	1.55	0.29
TMDL lake survey[2]	1,530	146	15.2	33	0.55	2.40	0.32
Kansas[1]	875	72	16.0	19	0.97	1.03	0.45
EPA Region VII area[1]	1,685	129	27.8	29	0.88	1.13	0.36
Trophic Criteria[1] (EPA Region VII)	700	35	20.0	8	--	--	0.23

[1]RTAG – EPA Region VII database (100 - 1000 acres) obtained from the Kansas Biological Survey.
[2]Small – medium size of TMDL lakes surveyed in 2002 and 2003.

As indicated in **Figures 3 and 5**, Lake Anthony frequently experiences low clarity. Non-algal turbidity values, derived from both Secchi depth and Chla values, if greater than 1 indicate inorganic particles are important in creating turbidity while values less than 0.4 tend to indicate very low levels of suspended silts and/or clay (Carney, 2004). During 1987 – 2004, non-algal turbidity values ranged from as low as 3.3 in 8/20/1990 to as high as 16.7 in 7/31/1989, with an average value of 8.3, indicating that inorganic turbidity was the major factor of light limitation, which strongly affected the biological activities due to nutrient enrichment in the water column.

Figure 6 shows common water quality patterns observed in Lake Anthony. In general, negative relationships were found between Chla and turbidity and rainfall while positive relationships were found between turbidity and rainfall, and Secchi and Chla. Two distinct biological processes appeared to govern Lake Anthony's water quality; microbial and primary (or algal) production activities (**Figure 7**). When the lake was turbid due to runoff events, microbial activities dominated. Because of decomposition and mineralization (i.e., ammonification and nitrification) of organic matter, the lake typically had lower pH and dissolved oxygen (DO) values and higher ammonia and nitrate/nitrite concentrations (**Figure 8**). There were three incidents (7/27/1987, 7/22/1992 and 8/14/2000) that DO values were close to 5 mg/L of aquatic life support criterion because the warm weather supported these high microbial respiratory activities in either the water column or sediment. According to a recent lake survey (Carney, 2004), the DO decline rate was calculated to be 1.60 mg/L per meter, which was identical to the 2000 record (Carney, 2000). However, when less rainfall occurred in the watershed and/or the lake was calm, the sunlight readily penetrated and algal production reached maximum. As a result, higher DO and pH values and lower nutrients appeared commonly. Table 2 shows detailed temperature, DO, pH and nutrient concentrations by depth at Station LM048801 during 1987 – 2004.

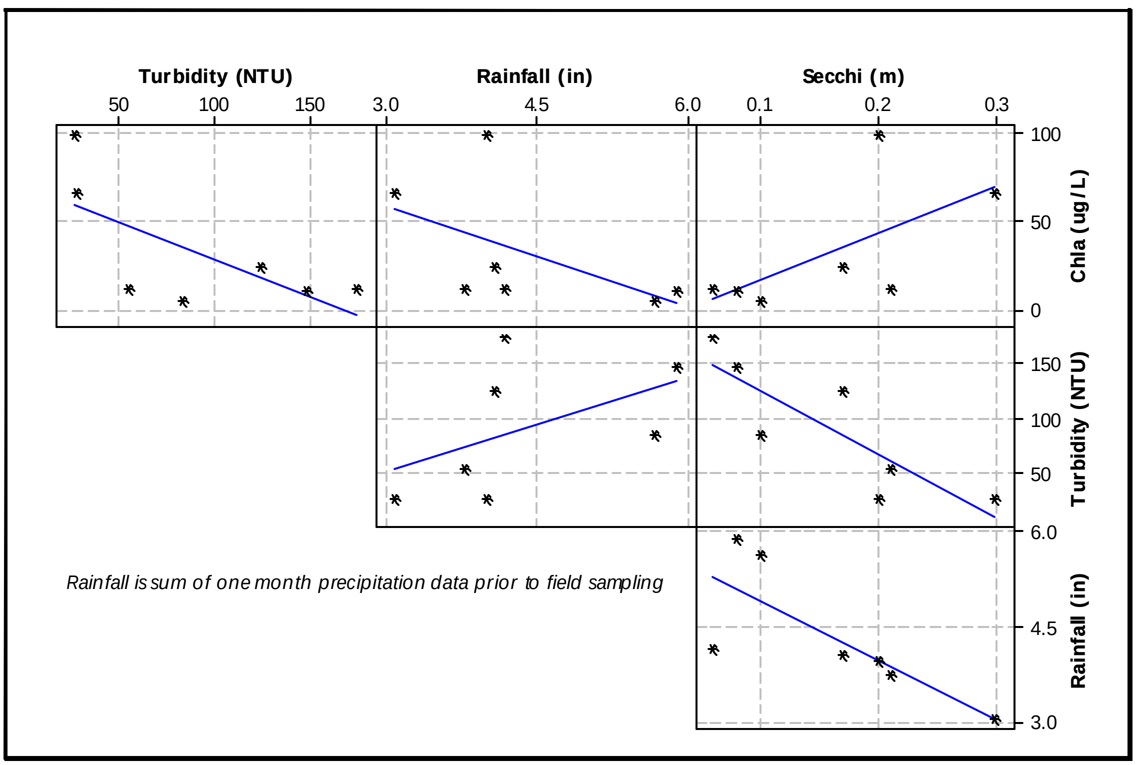

Figure 6. Common water quality patterns in Lake Anthony during 1987 – 2004.

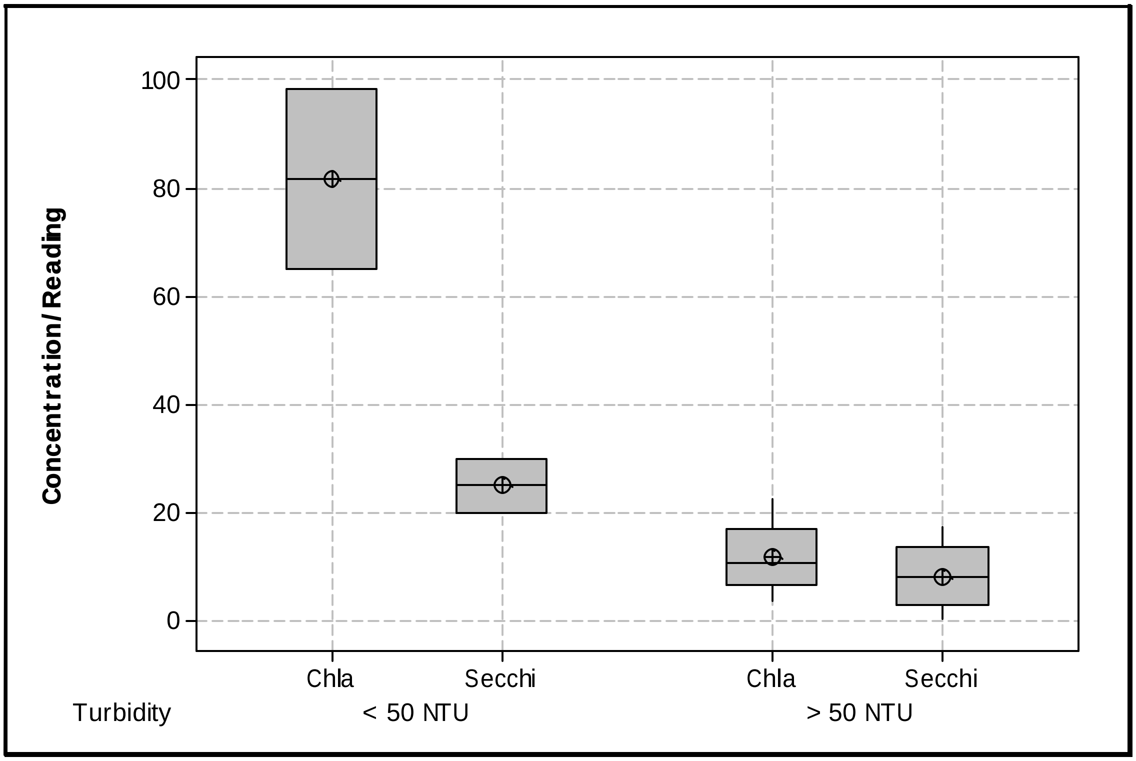

Figure 7. Chla and Secchi depth levels between two Lake Anthony data groups (> 50 NTU vs. < 50 NTU).

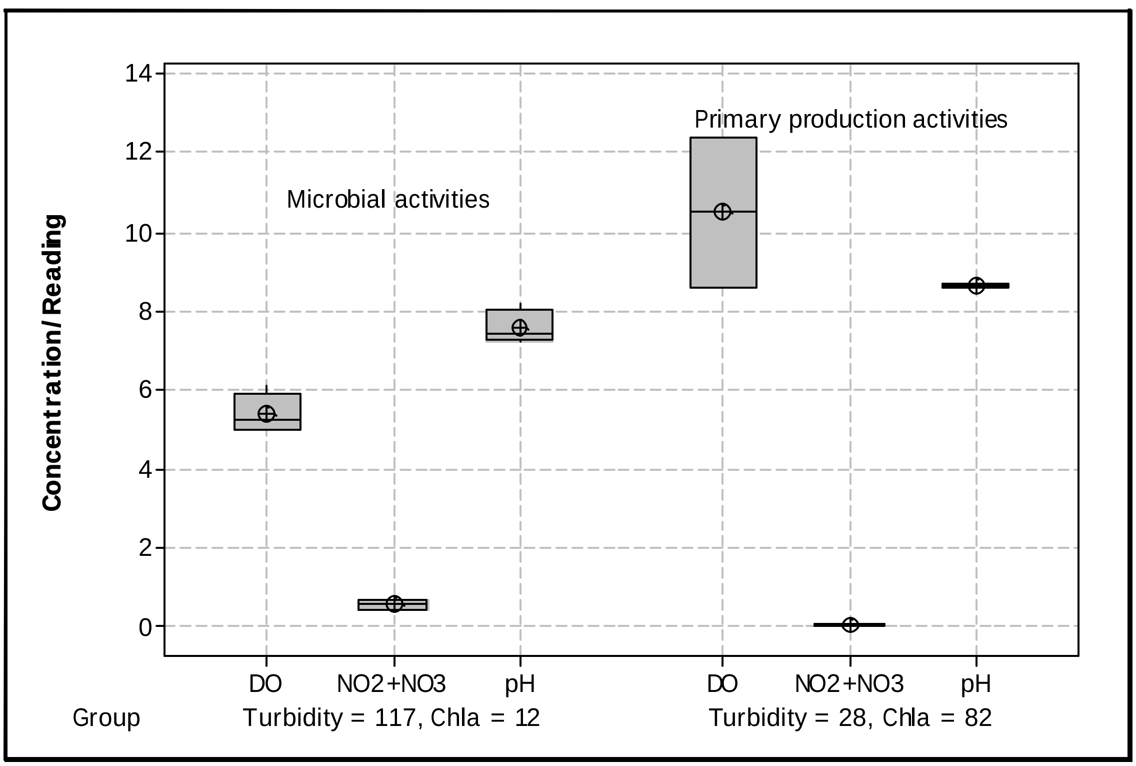

Figure 8. DO, nitrate/nitrite and pH levels between two Lake Anthony data groups (> 50 NTU vs. < 50 NTU), with grouping average values of turbidity and Chla.

Table 2. Temperature, DO, pH and nutrient concentrations by depth during 1987 – 2004.

Date	Depth	DO	Temp	pH	NH3	NO3	NO2	NO2+NO3	TKN	TP
	m	mg/L	°C		mg N/L	mg N/L	mg N/L	mg N/L	mg/L	mg/L
7/27/1987	00.0	5.6	28							
	00.5	5.4	28	8.2	0.10			0.50		0.20
	01.0	5.3	28							
	02.0	4.4	28							
	02.5			8.1	0.15			0.50		0.35
	03.0	4.0	27							
7/31/1989	00.0									
	00.5		28							
	04.5		25							
8/20/1990	00.0	10.7	31							
	00.5	8.6	28	8.7	0.11			0.00		0.22
	01.0	7.8	26							
	02.0	6.7	26	8.5	0.05			0.00		0.25
1/21/1992	00.5				0.22			0.67	0.50	0.30
7/22/1992	00.0	5.1	26							
	00.5	5.1	26	7.5	0.09			0.67	1.42	0.35
	01.0	5.1	25							
	02.0	4.7	25							
	03.0	3.6	25		0.15			0.66	1.53	0.42
	03.5	3.2	25							
6/17/1996	00.0	12.6	30							
	00.5	12.4	30	8.6	0.01	0.01	0.05	0.06	1.95	0.29
	01.0	11.8	30							
	01.5	8.1	28							
8/14/2000	00.0	5	28							
	00.5	5	27	7.2	0.28	0.65	0.05	0.70	1.90	0.30
	01.0	4.9	27							
	02.0	3.5	27	7.3	0.28	0.66	0.05	0.71	1.58	0.30
	02.5	0.1	27							
	03.0	0.1	27							
6/28/2004	00.0	6.2	25							
	00.5	6.1	25	7.4	0.10	0.38	0.09	0.46	1.25	0.27
	01.0	6.1	25							
	02.0	5.5	25	7.4	0.10	0.29	0.09	0.38	1.48	0.29
	02.5	2.2	24							

Figure 9 summarizes the current and possible future trophic conditions of Lake Anthony using a multivariate TSI compassion chart. TSI(Chla) – TSI(TP) is plotted on the vertical axis. Points below TSI(Chla) < TSI(TP) indicate situations where phosphorus may not be limiting Chla where points above TSI(Chla) > TSI(TP) indicate the opposite. TSI(Chla) – TSI(SD) is plotted on the horizontal axis, showing that if the Secchi depth (or SD) is greater than expected from the Chla trophic index, large organic materials dominate by zooplankton grazing. If the Secchi depth is less than expected from the Chla index, transparency is dominated by non-algal factors such as color or inorganic turbidity. Points near or on the diagonal line occur in turbid situations where phosphorus is bound to clay particles and therefore turbidity values are closely associated

with phosphorus concentrations (Dip-In, 2005). As indicated in **Figure 9**, Lake Anthony is a turbid lake dominated by inorganic particles and is N-limited. According to the most recent KDHE's lake survey, algal communities in Lake Anthony, based on cell count, was dominated by blue-green algae (Carney, 2004). It is well documented that under the N-limiting conditions blue-green algae have an adaptation advantage over other algae because of their ability to fix atmosphere N (Smith and Bennett, 1999).

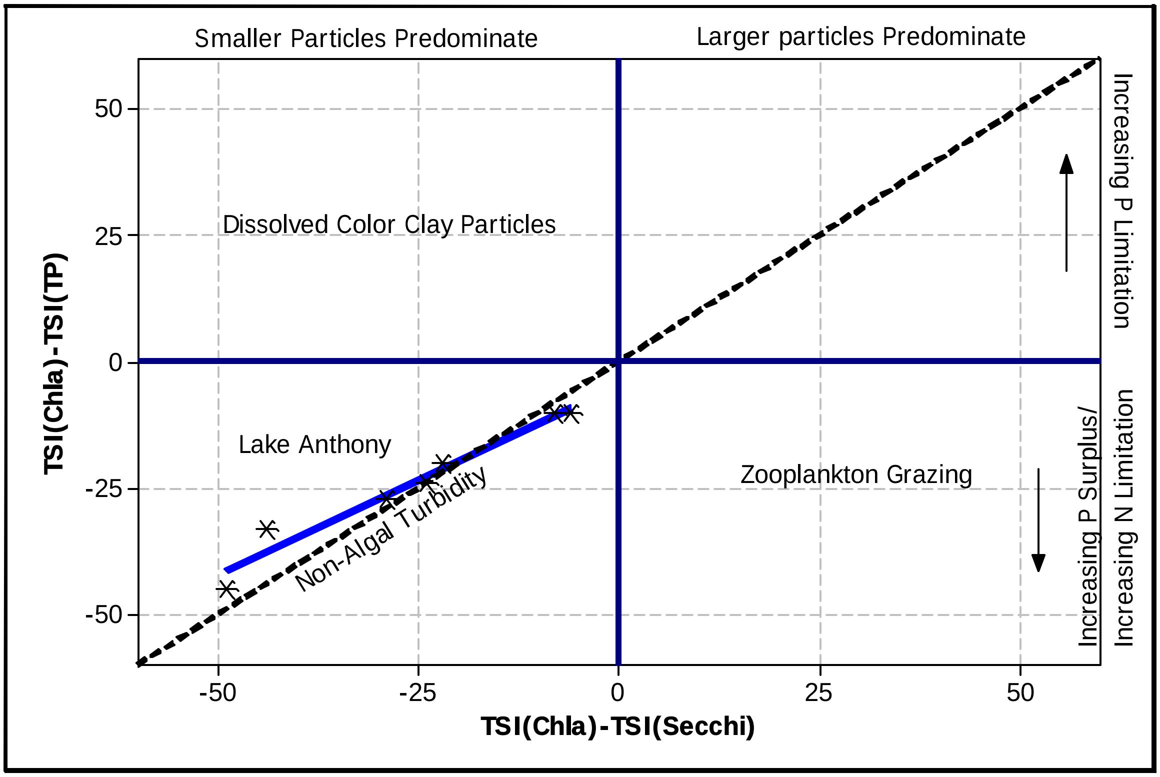

Figure 9. Multivariate TSI compassion chart of Lake Anthony

The fishery at Lake Anthony provides poor sport fishing opportunities. The number Stock or adult fish Captured Per Unit time Effort (Stock CPUE) shows that sight-feeding bass and crappie diminish in their populations especially in the recent years because of muddy water and flushing (**Figure 10**). Similarly, bottom-feeding fish like gizzard shad and channel catfish, in spite of any purchased and stocked over the past several years, follows the same pattern of the sight-feeding fish. Flushing over the dam is the probable reason for this reduction according to the Kansas Department of Wildlife and Parks (written commun., Gordon Schneider). Though sediment disturbance by these bottom feeders might cause turbidity and P recycling problems in the lake, their effects are only minor as compared to runoff events and wind-induced wave actions. As indicated in **Figure 11**, distributions of sight-feeding and bottom-feeding fish are closely associated with rainfall patterns. The pattern that sight-feeding fish in Lake Anthony are more abundant than bottom feeders is likely, in part, as a result of predator-prey relations that sight-feeding fish feed on bottom feeders and their tolerance to the flushing conditions.

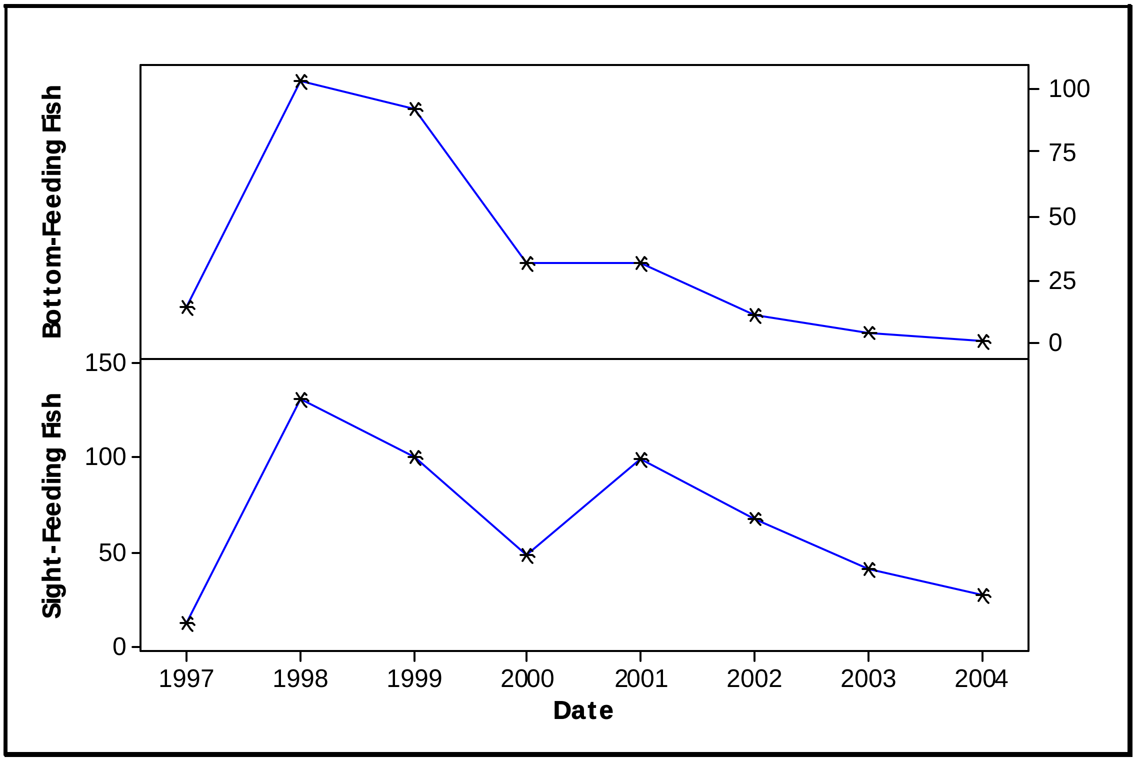

Figure 10. Stock CPUE for sight-feeding and bottom-feeding fish. [Sight-feeding fish are represented by large mouth bass (>8" in length) and white crappie (>5") whereas bottom-feeding fish are gizzard shad (>5") and channel catfish (>11").]

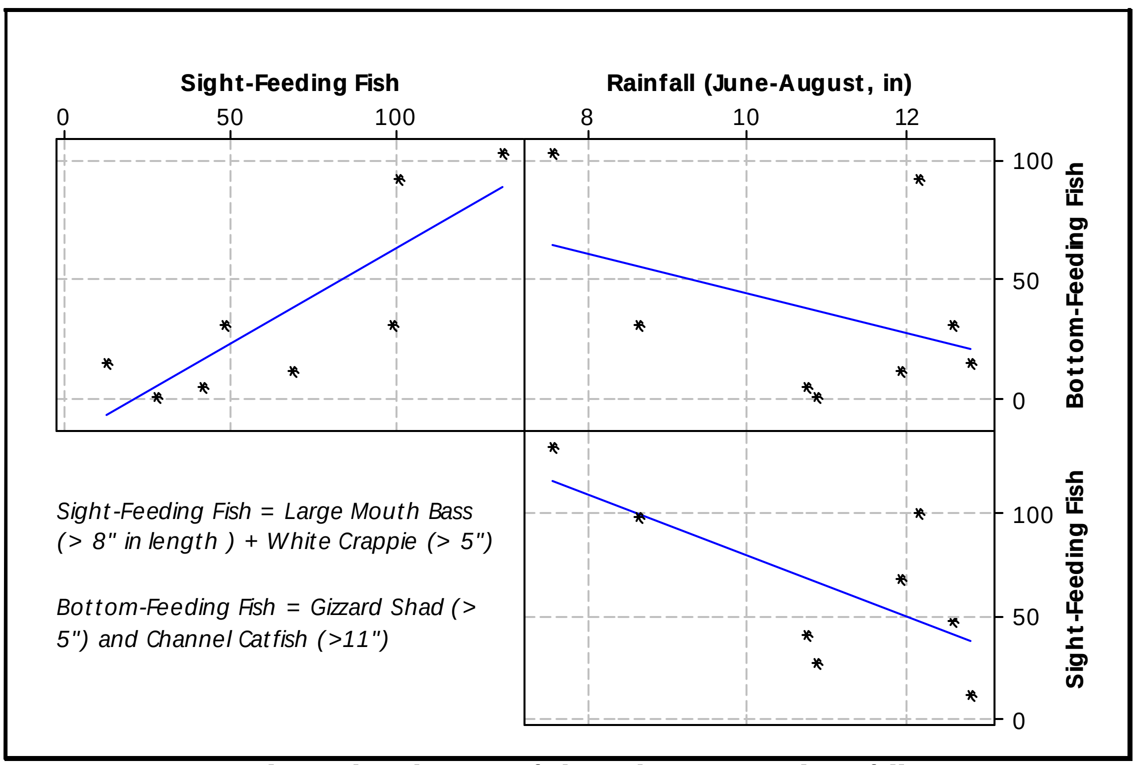

Figure 11. Relationships between fish stock CPUEs and rainfall in 1997-2004.

3. SOURCE INVENTORY AND ASSESSMENT

NPDES: The Chaparral High School is the only state permitted facility (M-AR04-NO02) within the watershed. The facility has a non-discharging one-cell lagoon system that may contribute nutrient load to Lake Anthony via Spring Creek under extreme precipitation events (stream flows associated with such events are typically exceeded only 1 - 5 % of the time). All non-discharging lagoon systems are prohibited by the state from discharging to the surface waters. Under standard conditions of these non-discharging facility permits, when the water level of the lagoon rises to within two feet of the top of the lagoon dikes, the permit holder must notify KDHE. Steps may be taken to lower the water level of the lagoon and diminish the probability of a bypass of sewage during inclement weather. Bypasses may be allowed if there are no other alternatives and 1) it would be necessary to prevent loss of life, personal injury or severe property damage; 2) excessive stormwater inflow or infiltration would damage the facility; or 3) the permittee has notified KDHE at least seven days before the anticipated bypass. Any bypass is immediately reported to KDHE.

Land Use: The predominant land use is cultivated cropland, which accounts for 71% of the total land area in the watershed (**Figure 12**). Urban area, such as residential, commercial and industrial uses, only comprises less than 1% of the watershed. Approximately 2% of the land is occupied either by Ash-Elm Hackberry/Cottonwood floodplain forest or Cottonwood/deciduous woodland, whereas 7% is tall grass prairie. The area under the Conservation Reserve Program (CRP) only accounts for about 3% (360 acres) of the entire watershed. There are about 785 acres of riparian area (30-meter buffer along the stream system) in the watershed and the cropland occupies 29% of the total riparian buffer area. Ash-Elm Hackberry and Cottonwood floodplain forest/woodland, mix prairie and non-native grassland account for about 8%, 4% and 30%, respectively. Approximately 4% of the stream buffer area is CRP (26 acres). The riparian-related land use information was derived from KDHE rivershed data.

Livestock Waste Management Systems: Only one confined cattle feedlot operation (Permit No: A-ARHP-BA03) is certified within the watershed. This beef feedlot operation is located at the central area of the watershed, just about 1.5 miles south-west from Harper City. The facility consists of 7 acres of dirt lots which drain onto adjacent cropland. The maximum allowable animal number for this facility is 450 head. According to the maintenance requirement, open lots used on a continuous basis shall be cleaned of manure accumulations after each occupancy cycle or at least twice per year. If used seasonally, they should be cleaned of manure after each use and planted to nitrogen-using cover crop during the empty periods. Liquid livestock wastes should be applied to land only on days when no precipitation occurs and have been immediately preceded by at least three successive days with less than 0.05 inches of rainfall per day. All of the livestock wastes shall be applied to the land using rates and methods that prevent surface runoff of pollutants and the leaching of pollutants to groundwater. Any damaged vegetation in runoff filtration/infiltration areas shall be promptly re-established, and runoff filtration/infiltration areas shall also be maintained free of channels or gullies. Though the total potential number of animals is 450 in the watershed, the actual number of animals is typically less than the maximum allowable number.

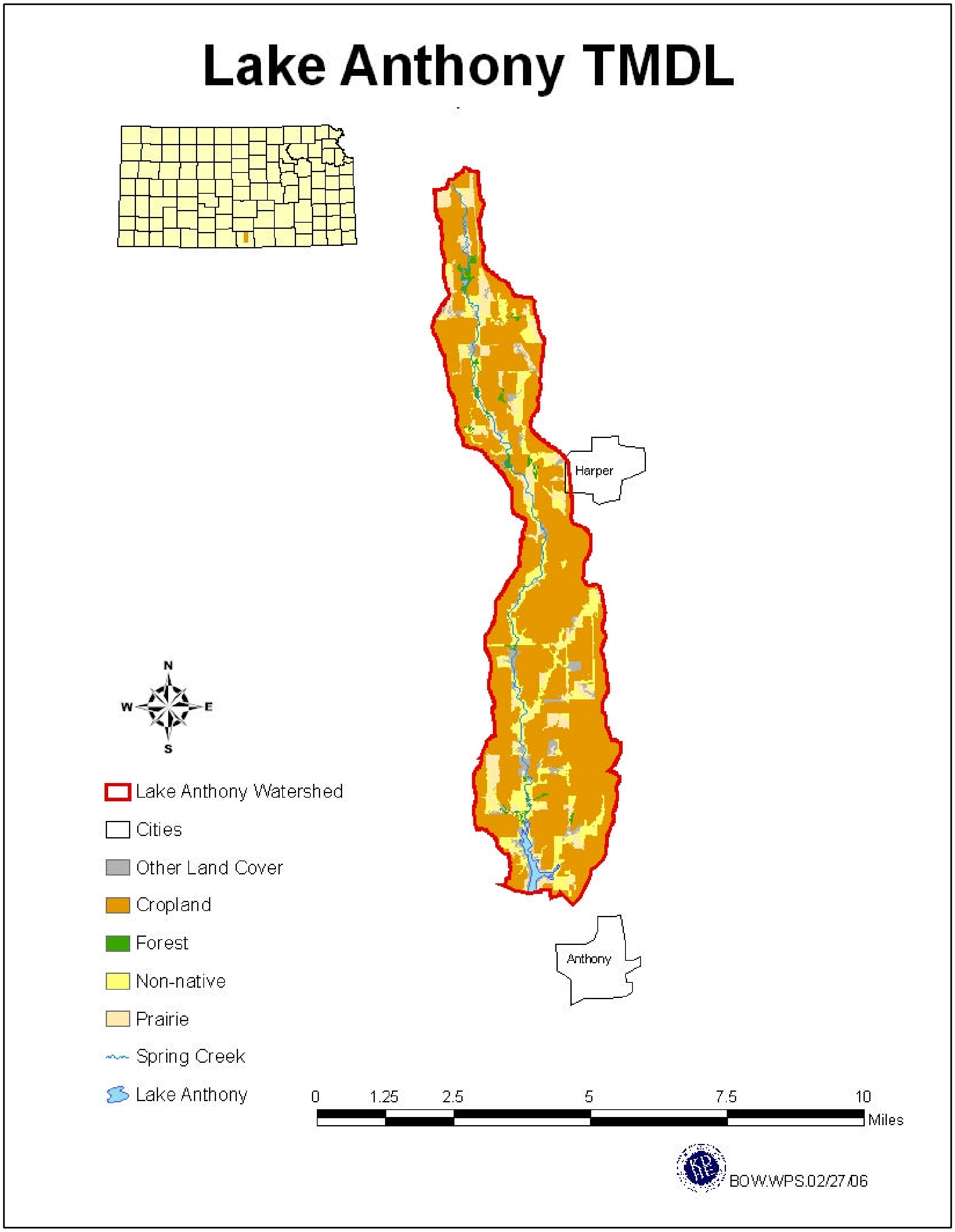

Figure 12. Land use/land cover of Lake Anthony Watershed

On-Site Waste Systems: According to the 2000 census data from the U.S Census Bureau, the population of the entire watershed was 250 people, and therefore the watershed population density is relatively high (12 people/sq. mile) when compared to the density of Harvey County (8 people/sq. mile). County-wise estimation indicates that the population has decreased by approximately 8% since 1990 (**Table 3**). Based on the 1990 census data, about 30% of the households in Harvey County are on septic systems. Because this watershed is a rural, agricultural area, many of the farm houses are not connected in a public sewer system, failing on-site systems may contribute significant nutrient loadings and aggravate eutrophication problems under the low flow conditions.

Table 3. Summary of urban and rural community comparisons between 1990 and 2000 for Harvey County (the decennial data was from the U.S. Census Bureau).

Type	Description	1990[†]	2000
Urban	Inside urbanized areas	0	0
	Inside urban clusters (Outside urbanized areas[†])	2,516	0
Rural	Farm	700	637
	Non-farm	3,908	5,897

Contributing Runoff: The Lake Anthony watershed's average soil permeability is 1.8 inches/hour according to Kansas Mean Soil Permeability data base from Kansas Geological Survey. About 70% of the watershed produces runoff even under relative low (1.5"/hr) potential runoff conditions. Under very low (< 1"/hr) potential conditions, the potential contributing area is greatly reduced (60%). Runoff is chiefly generated as infiltration excess with rainfall intensities greater than soil permeabilities. As the watersheds' soil profiles become saturated, excess overland flow is produced. Generally, storms producing less than 0.5"/hr of rain will generate runoff from 15% of this watershed.

Background Levels: Eight percent of 30-m riparian buffer areas are covered by forest/woodland and about 50% of the riparian areas are occupied by either CRP, or native or non-native prairie; leaf and grass litter may be contributing to the nutrient loading. The atmospheric phosphorus and geological formations (i.e., soil and bedrock) may also contribute to phosphorus loads. Because Lake Anthony is a small shallow lake, nutrient cycling of the sediment (from wind mixing and bottom feeding fish) is likely contributing available nutrients to the lake for algal uptake. Because the orientation of the lake is parallel to the prevailing wind directions, some resuspension of sediment may contribute turbidity to the lake. Likewise, bottom feeding fish may also re-suspend the sediment and thus contribute some turbidity. However, as compared to wind-induced turbidity, this biological (fish) turbidity is likely to be minor.

4. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY

Point Sources: A current Wasteload Allocation of zero is established by this TMDL because of the lack of discharging point sources in the watershed. Should future point sources be proposed in the watershed and discharge into the impaired lake, the current wasteload allocation will be revised by adjusting current load allocations to account for the presence and impact of these new point source dischargers.

Non-Point Sources: Siltation and nutrient loading come predominantly from nonpoint source pollution. Given the soil characteristics (fine silt and very erosive soil) of the watershed, overland runoff can easily carry sediment to the stream segments and eventually to the lake. Though Kansas does not have numeric water quality criteria for inorganic turbidity associated with soil/sediment particles (often referred to as non-algal turbidity), "Brown" scores, derived from 1998-2002 statewide lake monitoring (Carney, 2002), were used here as a guideline because of the appearance of low water clarity as a result of non-algal turbidity (**Figure 9**). To achieve full support status – the waterbody being fully supportive all of its designated uses, 70 cm of Secchi depth is targeted as the TMDL and watershed management goals of restoring water quality in Lake Anthony.

As indicated in **Figure 13**, total suspended solids (TSS) showed a strong relationship with Secchi depth. The average TSS and Secchi depth are 63 mg/L and 0.16 m, respectively. The target TMDL TSS and Secchi depth are 4 mg/L and 0.70 m, respectively, suggesting that a 94% TSS reduction is necessary to reach the endpoint, a Secchi depth of 0.7 m.

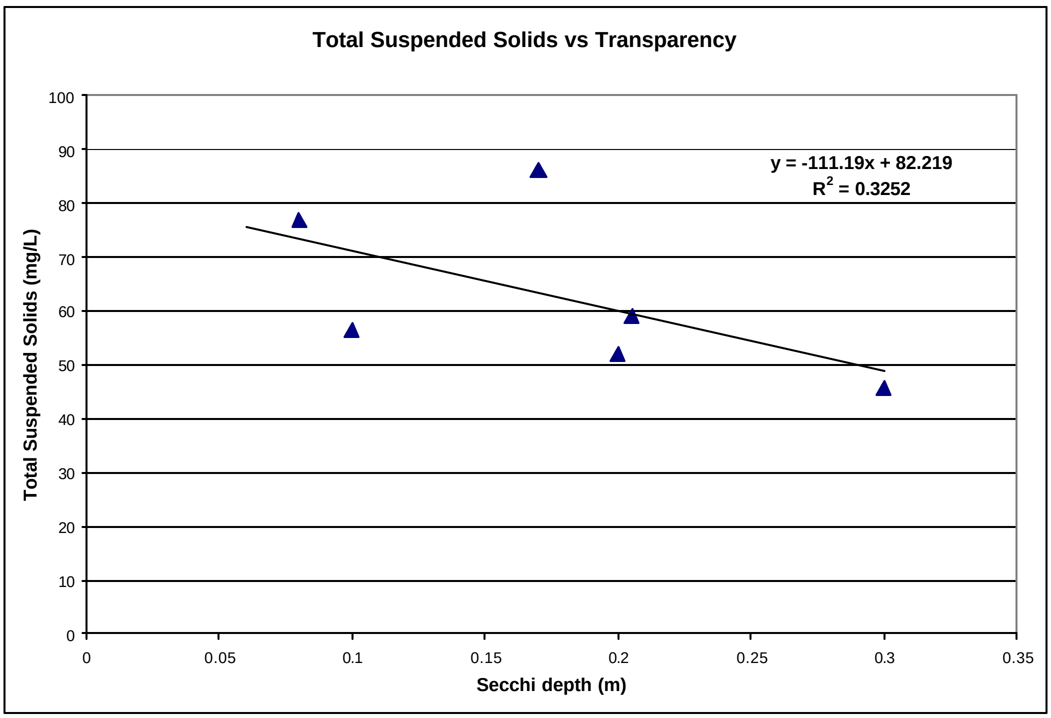

Figure 13. Relationships between TSS and Secchi depth in 1987 – 2004.

Based on lake retention time, TSS concentration and dam trapping efficiency, the sediment exiting the lake annually is calculated to be:

> [Lake Volume (657 ac-ft)]*[TSS (63 mg /L)]*[Lake Retention Time (365 days/84 days)]*[Unit Conversion Factors (1,233,482 L/ac-ft)(2.204 lbs/10^6 mg)(1 ton/2000 lbs)] = 244 tons of TSS (or sediment)

> Total amount of sediment exported from the watershed = $\frac{244}{0.1}$ = 2,440 tons (0.18 ton/ac).

Assuming a 90% trapping efficiency of the lake, the amount of sediment accumulated on the lake bottom annually is 2,440 – 244 = 2196 (tons). **Table 4** summarizes the load comparisons between the TSS calculation and the results of the AGricultural NonPoint Source pollution (AGNPS) model simulated in the early 1990s'.

The target TMDL TSS load is calculated as:

[Lake Volume (658 ac-ft)]*[TSS (4 mg /L)]*[Lake Retention Time (365 days/84 days)]*[Unit Conversion Factors (1,233,482 L/ac-ft)(2.204 lbs/10^6mg)(1 ton/2000 lbs)] = 16 tons of TSS (or sediment)

Total amount of sediment exported from the watershed = $\frac{16}{0.1}$ = 160 tons (0.01 ton/ac).

Amount of sediment accumulated on the lake bottom annually is 160 – 16 = 144 (tons), assuming a 90% trapping efficiency of the lake.

Table 4. Comparison summary between load calculation between TSS and AGNPS.

Secchi depth (m)	TSS (mg/L)	TSS load (ton/yr) existing	TSS load (ton/yr) accumulating	Sediment load (TSS) (ton/yr)	Total sediment load (AGNPS) (ton/yr)
0.16	63	244	2,196	2,440	3,171

To control elevated Chla levels and associated aesthetic problems in the lake, watershed nutrient reduction management practices need to be implemented. For eutrophication assessment, the BATHTUB model was used. BATHTUB is an empirical receiving water quality model, that was developed by U.S. Army Corps of Engineers (Walker, 1996), and has been widely used in the nation to address many TMDLs relating to issues associated with morphometrically complex lakes and reservoirs (Mankin et al., 2003; Wang et al., 2005).

BATHTUB was calibrated based on existing data. For Lake Anthony, the loads were estimated from the previous results of AGNPS (Carney, 1993) and USGS long-term flow records outlined in Section 2 while climatic related information was gathered from the NCDC. The BATHTUB setting and nutrient model selections are provided in Appendix A.

Lake Anthony is designated as a Class A Primary Contact Recreation. According to the state eutrophication TMDLs (http://www.kdheks.gov/tmdl/eutro.htm), 12 µg/L of Chla is targeted for primary contact recreation lakes (i.e., swimming and domestic water supply) whereas the 20 µg/L of Chla is implemented for secondary contact recreation lakes (i.e., fishing). Based on modeling results, a 70% nutrient (TN and TP) reduction is required to reach the endpoint as opposed to approximately 85% of TP reduction (**Figure 14**). Because Lake Anthony is a N-limited lake, Load Allocation is set, based on TN and TP, to 6,611 lbs/yr for TN and 711 lbs/yr for TP, instead of TP only.

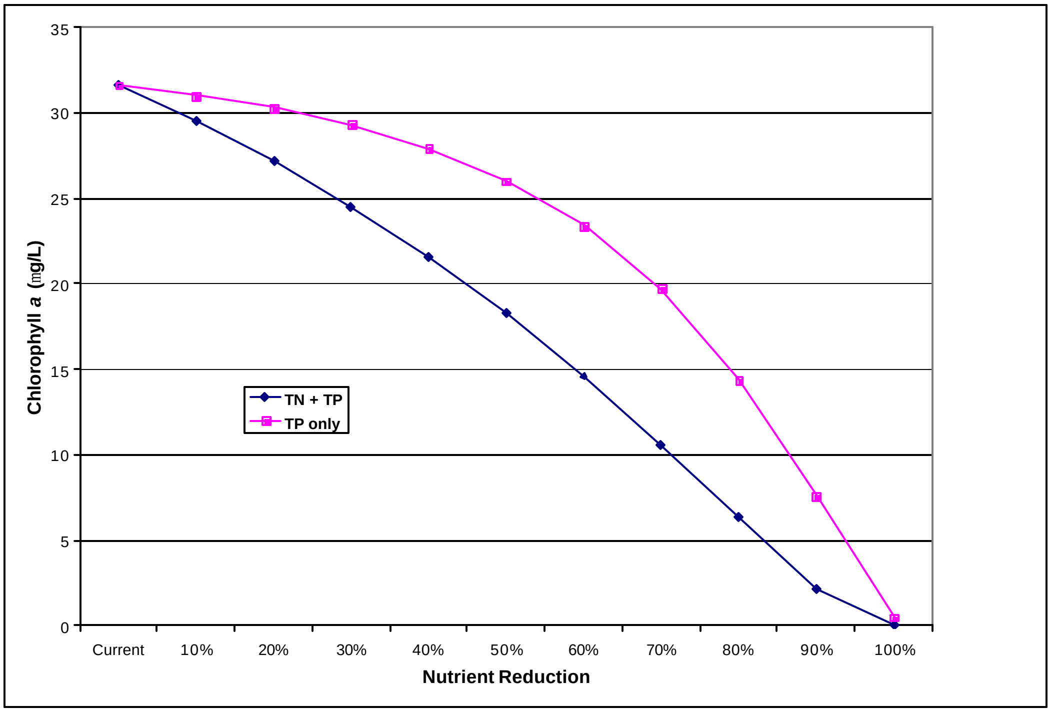

Figure 14. Changes in Chla levels in relation to watershed nutrient reduction.

Defined Margin of Safety: The Margin of Safety is explicit and established by setting TSS allocations for the primary source of sediment to Lake Anthony at an annual rate of 16 tons (10%) taken from the total load to ensure that adequate load reduction occurs to meet the endpoint. For nutrients, the explicit margin of safety will be 661 lbs/yr and 71 lbs/yr for TN and TP, respectively.

State Water Plan Implementation Priority: Because this lake has indicated problems with siltation and eutrophication accompanying low pH and DO issues, which may have short-term and immediate consequences for aquatic life, this TMDL will be a High Priority for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Chikaskia Basin (HUC 8: 11060005) with a priority ranking of 30 (Medium Priority for restoration work).

5. IMPLEMENTATION

Desired Implementation Activities

There is a good potential that agricultural best management practices will improve the water quality in Lake Anthony. Some of the recommended agricultural practices are as follows:

1. Promote and adopt continuous no-till cultivation to increase the amount of water infiltration and minimize cropland soil erosion and nutrient transports,
2. Perform soil tests and apply nutrient best management practices (BMPs) to reduce nutrient additions to the lake from excess fertilization,

3. Maintain and improve grass buffers and filterstrips along streams and channels in the watershed,
4. Maintain and expand the areas of CRP in the watershed,
5. Reduce activities within riparian areas,
6. Connect septic systems around the lakeshore development area to a public sewer system to reduce direct nutrient inputs to the lake,
7. Construct ponds/detention basins, erosion control structures and/or wetlands to reduce soil erosion and to trap sediment and low peak runoff rates, and
8. Dredge the lake to improve average depth of the lake and remove undesired sediment-bound nutrients.

For example, **Figure 15** shows the improvement of Secchi depth and corresponding percent No-Till cropland conversion in the watershed using the Spreadsheet Tool of Estimating Pollutant Load (STEPL) model. Converting 52% of the cropland can increase Secchi depth from 0.16 m, currently, to 0.2 m. If No-Till farming is implemented in all of the cropland, Secchi depth will increase to 0.48 m. By converting 1,000 ac of the conserved cropland to grassland, Secchi depth will increase to 0.5 m. The conversion of cropland to grassland should target the critical area that has low soil permeability (or high runoff potential) (**Figure 16**). To reach the TMDL endpoint (0.7 m), 94% of the total watershed area needs to be converted to pristine conditions (tall grass prairies).

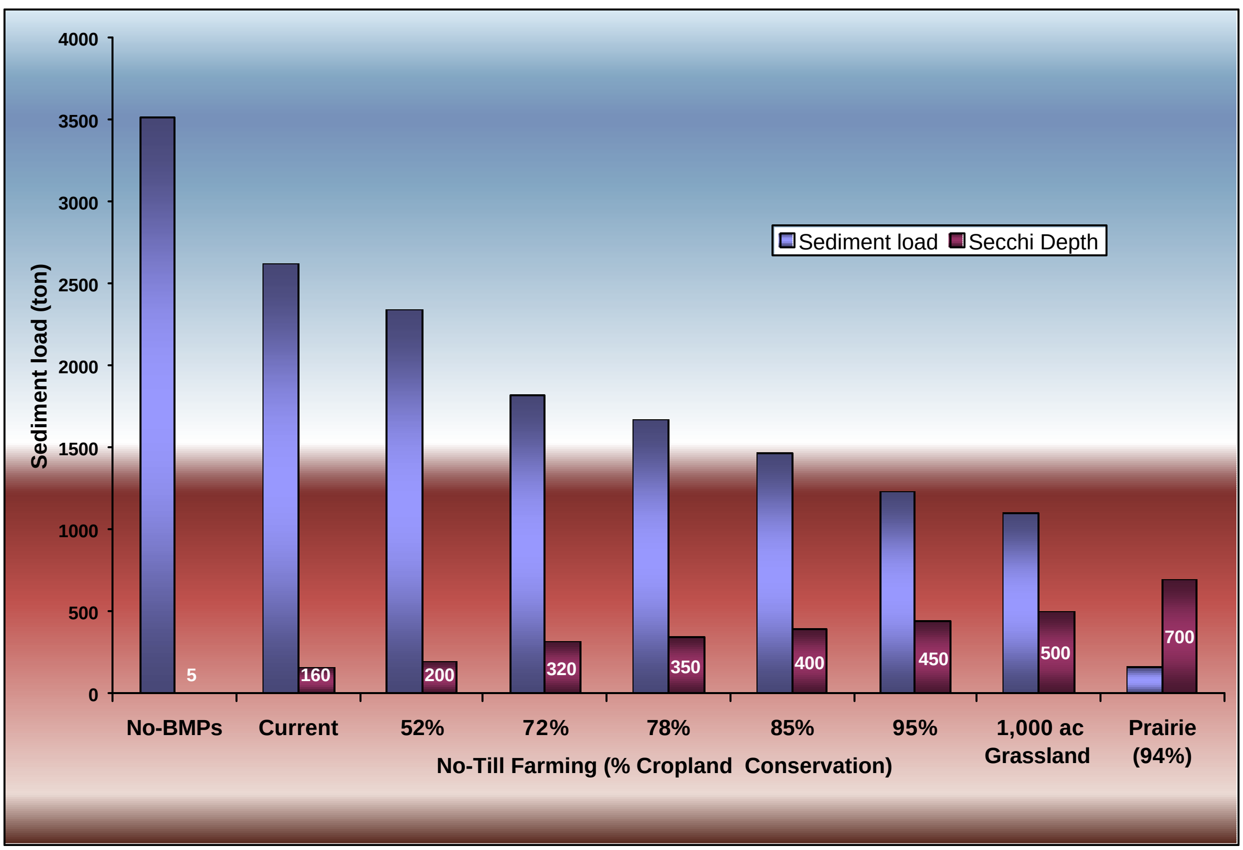

Figure 15. Relationships between sediment loads and Secchi depth readings for various selected land management. (Secchi depth values are in one-thousandth of a meter.)

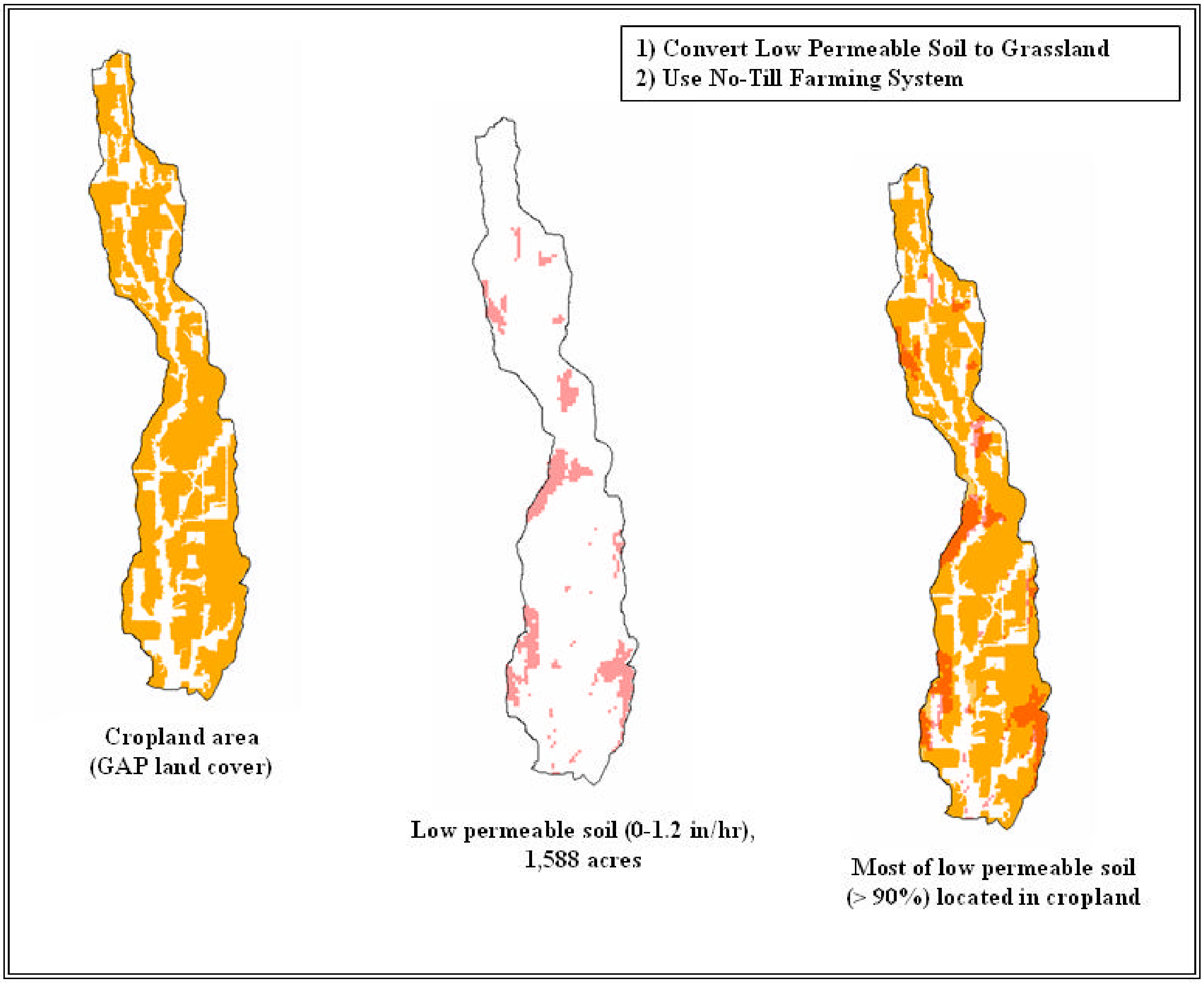

Figure 16. An example of watershed BMPs – targeted cropland conversion to grassland.

Implementation Programs Guidance

Fisheries Management - KDWP

a. Assist evaluation in-wetland or near-wetland potential sources of sediment to wetland,

b. Advise the city of Anthony and Harper County on applicable wetland management techniques which may reduce sediment loading and cycling in wetland, and

c. Gordon Schneider (2005) indicated that "*although a minor component of the turbidity problem, any effort to manage the turbidity should address sediment disturbance by bottom feeders such as carp and black bullheads. Management for predaceous sport fish species usually achieves control of these nuisance species (**Figure 11**). However, Lake Anthony has an uncontrolled spillway with no freeboard and a large drainage area to surface acre ratio of 121:1. Consequently, drastic changes in the fish population occur during floods due to flushing of fish downstream. Repeated loss of nearly the entire fish population thwarts standard fish management practices such as stocking or angling regulations. Any discussion of fish population diversity and dynamics as it relates to* *turbidity of the lake must recognize this problem. A spillway barrier to minimize loss of fish in flood events should be a primary goal of any fish management plan.*"

Nonpoint Source Pollution Technical Assistance - KDHE

a. Support Section 319 demonstration projects for reduction of sediment runoff from agricultural activities as well as nutrient management, and

b. Provide technical assistance on practices geared to the establishment of vegetative buffer strips

Water Resource Cost Share and Nonpoint Source Pollution Control Program - SCC

a. Apply conservation farming practices, including no-till, terraces and contours, sediment control basins, and constructed wetlands,

b. Provide sediment control practices to minimize erosion and sediment and nutrient transport, and

c. Conduct periodic bathymetric survey and evaluate quantity and quality of accumulated sediment on the lake bottom.

Riparian Protection Program - SCC

a. Establish or reestablish natural riparian systems, including vegetative filter strips and streambank vegetation, and

b. Develop riparian restoration projects.

Buffer Initiative Program - SCC

a. Install grass buffer strips near streams, and

b. Leverage Conservation Reserve Enhancement Program to hold riparian land out of production.

Extension Outreach and Technical Assistance - Kansas State University

a. Educate agricultural producers on sediment, nutrient, and pasture management,

b. Provide technical assistance on buffer strip design and minimize cropland runoff, and

c. Continue to educate residents and landowners about nonpoint source pollution.

Reasonable Assurances:

Authorities: The following authorities may be used to direct activities in the watershed to reduce pollution.

1. K.S.A. 65-164 and 165 empowers the Secretary of KDHE to regulate the discharge of sewage into the waters of the state.

2. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.

3. K.A.R. 28-16-69 to -71 implements water quality protection by KDHE through the establishment and administration of critical water quality management areas on a watershed basis.

4. K.S.A. 2-1915 empowers the State Conservation Commission to develop programs to assist the protection, conservation and management of soil and water resources in the state, including riparian areas.

5. K.S.A. 75-5657 empowers the State Conservation Commission to provide financial assistance for local project work plans developed to control non-point source pollution.

6. K.S.A. 82a-901, *et seq*. empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.

7. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the *Kansas Water Plan*.

8. The *Kansas Water Plan* and the Lower Arkansas River Basin Plan provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.

9. K.S.A. 32-807 authorizes Kansas Department of Wildlife and Parks to manage lake resources.

Funding: The State Water Plan Fund annually generates $16-18 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the *Kansas Water Plan*. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watersheds and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. This watershed and its TMDL are a High Priority consideration.

Effectiveness: Improvements in sediment and nutrient loads to the lake can be accomplished through appropriate management and control systems, including buffer strips and riparian restoration projects.

6. MONITORING

KDHE will continue its 4-yr sampling schedule in order to assess the impairment that drives this TMDL. Based on that sampling, the priority status of 303(d) listing will be evaluated in 2012. Should impaired status be verified, the desired endpoints under this TMDL will be refined and direct more intensive sampling will need to be conducted during the growing season over the period 2010-2012 to assess progress in this TMDL's implementation.

7. FEEDBACK

Public Meetings: A meeting was held at the City of Anthony on August 9 2006 to discuss Lake Anthony's TMDLs and watershed management plans. Interest groups included the city, Natural Resources Conservation Services, Lake Anthony Board, and Sunflower RC & D area, Inc. An active Internet site was established at http://www.kdheks.gov/tmdl/public.htm to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Lower Arkansas Basin.

Public Hearing: A Public Hearing on the TMDL of the Lower Arkansas Basin will be held at the Kansas Department of Transportation Building, Hutchinson, KS on September 13, 2006.

Basin Advisory Committee: The Lower Arkansas Advisory Committee met to discuss the TMDLs in the basin on March 8, 2006.

Milestone Evaluation: In 2011, evaluation will be made as to the progress of watershed implementation activities.

Consideration for 303(d) Delisting: The lake will be evaluated for delisting under Section 303(d), based on the monitoring data in 2008 and 2012. Therefore, the decision for delisting will come about in the preparation of the 2014 303(d) list. Should modifications be made to the applicable water quality criteria during the intervening implementation period, consideration for delisting, desired endpoints of this TMDL and implementation activities may be adjusted accordingly.

Incorporation into Continuing Planning Process, Water Quality Management Plan and the Kansas Water Planning Process: Under the current version of the Continuing Planning Process (CPP), the next anticipated revision will come with the adoption of the new EPA Watershed Rule which will emphasize implementation of TMDLs. At that time, incorporation of this TMDL will be made into the CPP. Recommendations of this TMDL will be considered in *Kansas Water Plan* implementation decisions under the State Water Planning Process after Fiscal Years 2008-2011.

Revised August 18, 2006

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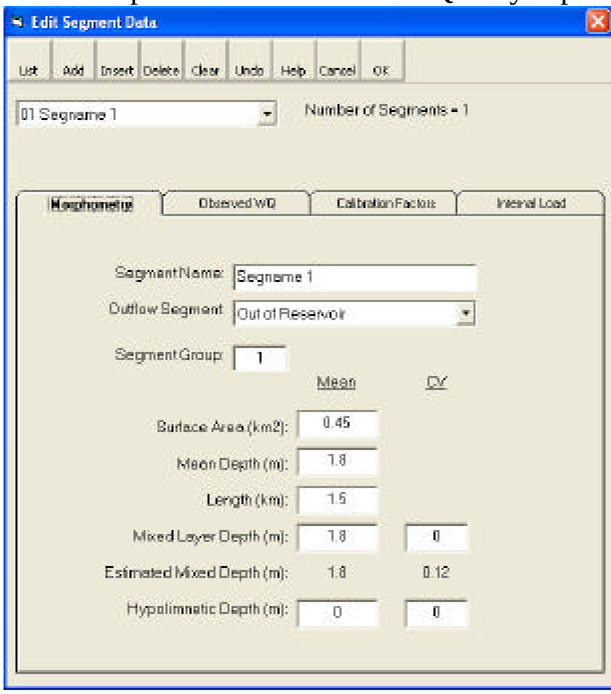
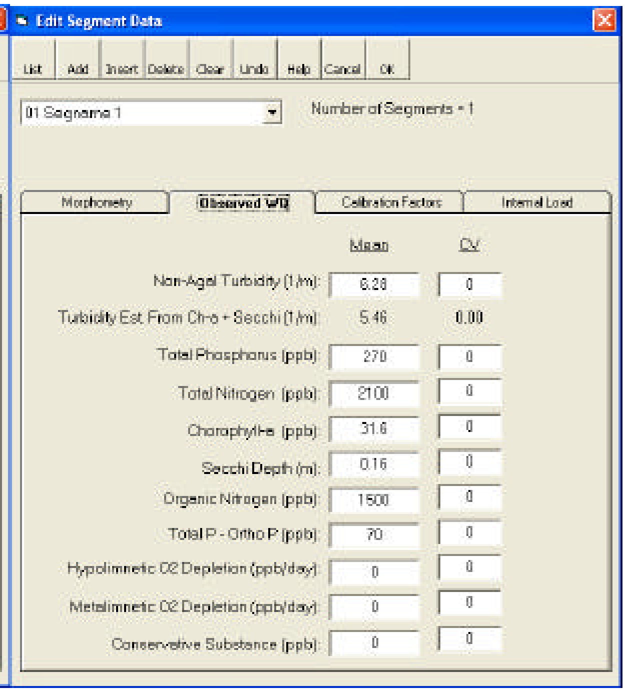
Appendix A

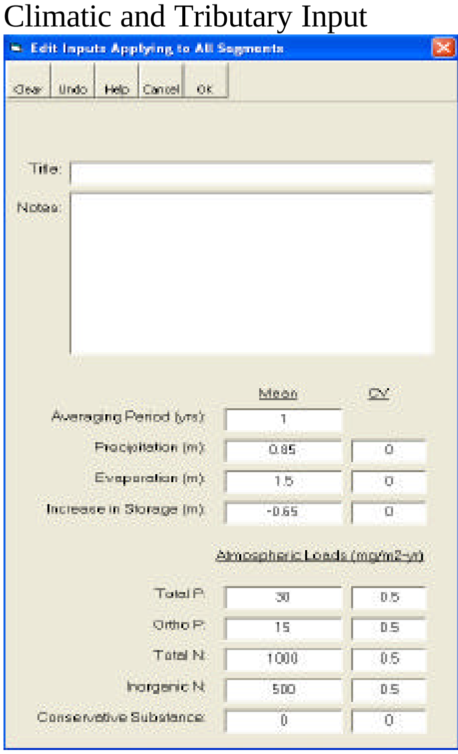
BATHTUB Input and Output Files

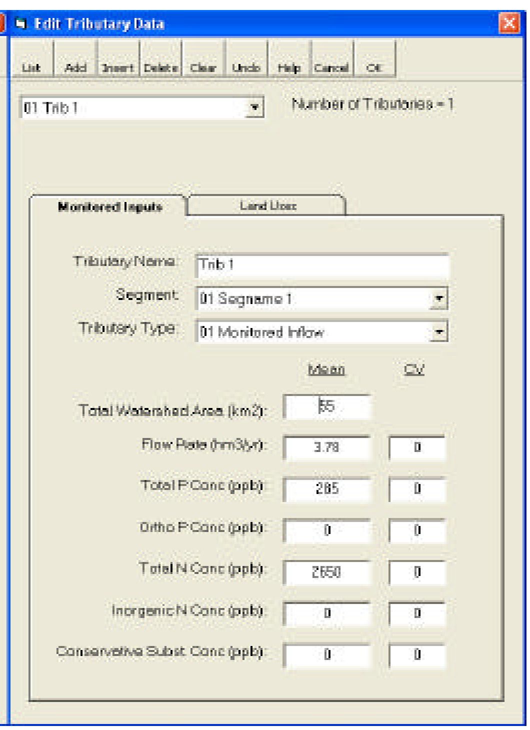
Lake Morphometrical and Water Quality Input



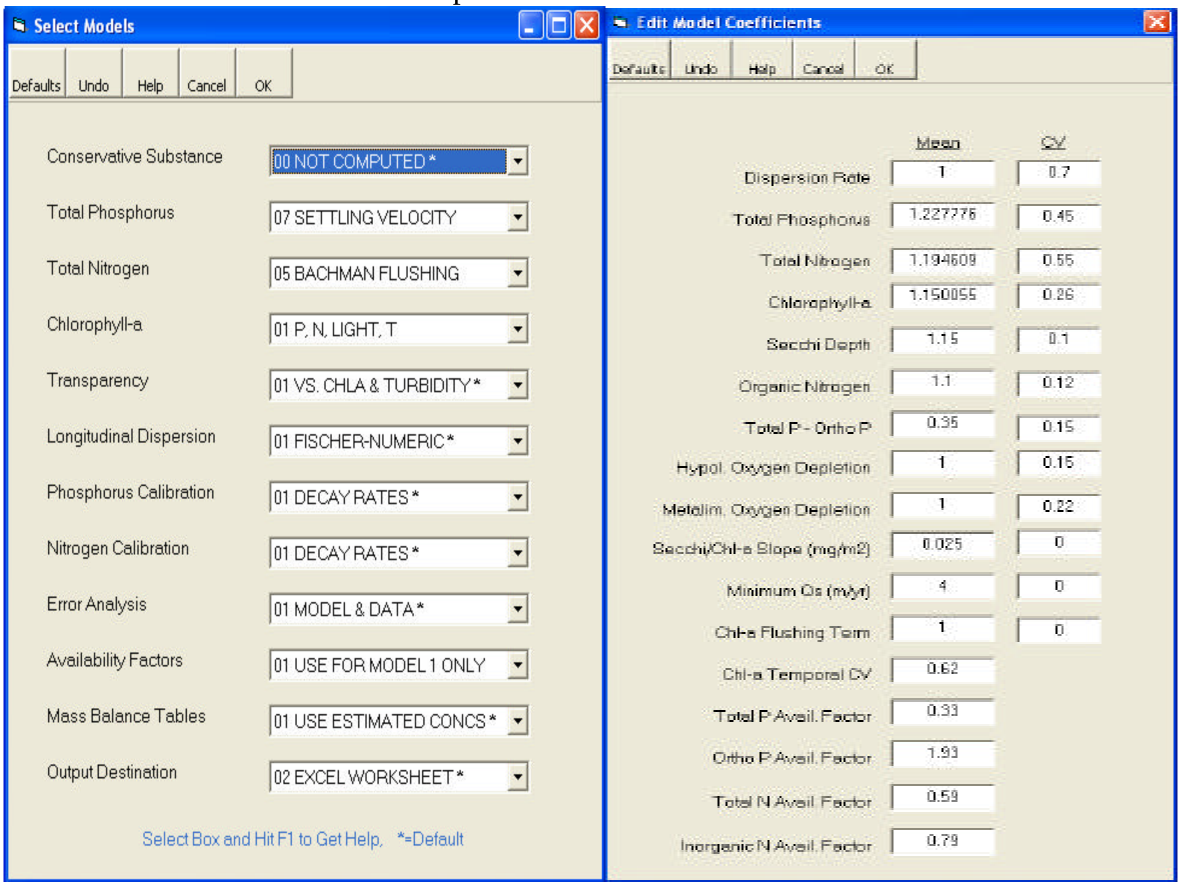


Climatic and Tributary Input

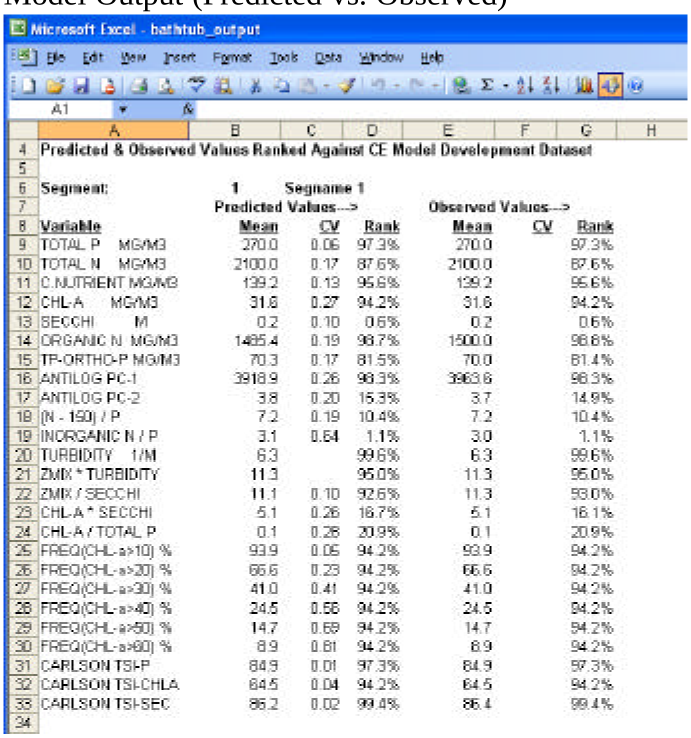




Model Selection and Coefficient Input



Model Output (Predicted vs. Observed)



Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 Segname 1

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	270.0	0.06	97.3%	270.0		97.3%
TOTAL N MG/M3	2100.0	0.17	87.6%	2100.0		87.6%
C.NUTRIENT MG/M3	139.2	0.13	95.6%	139.2		95.6%
CHL-A MG/M3	31.6	0.27	94.2%	31.6		94.2%
SECCHI M	0.2	0.10	0.6%	0.2		0.6%
ORGANIC N MG/M3	1485.4	0.19	98.7%	1500.0		98.8%
TP-ORTHO-P MG/M3	70.3	0.17	81.5%	70.0		81.4%
ANTILOG PC-1	3918.9	0.26	98.3%	3963.6		98.3%
ANTILOG PC-2	3.8	0.20	15.3%	3.7		14.9%
(N - 150) / P	7.2	0.19	10.4%	7.2		10.4%
INORGANIC N / P	3.1	0.64	1.1%	3.0		1.1%
TURBIDITY 1/M	6.3		99.6%	6.3		99.6%
ZMIX * TURBIDITY	11.3		95.0%	11.3		95.0%
ZMIX / SECCHI	11.1	0.10	92.6%	11.3		93.0%
CHL-A * SECCHI	5.1	0.26	16.7%	5.1		16.1%
CHL-A / TOTAL P	0.1	0.28	20.9%	0.1		20.9%
FREQ(CHL-a>10) %	93.9	0.06	94.2%	93.9		94.2%
FREQ(CHL-a>20) %	66.6	0.23	94.2%	66.6		94.2%
FREQ(CHL-a>30) %	41.0	0.41	94.2%	41.0		94.2%
FREQ(CHL-a>40) %	24.5	0.56	94.2%	24.5		94.2%
FREQ(CHL-a>50) %	14.7	0.69	94.2%	14.7		94.2%
FREQ(CHL-a>60) %	8.9	0.81	94.2%	8.9		94.2%
CARLSON TSI-P	84.9	0.01	97.3%	84.9		97.3%
CARLSON TSI-CHLA	64.5	0.04	94.2%	64.5		94.2%
CARLSON TSI-SEC	86.2	0.02	99.4%	86.4		99.4%